

California Pest Rating Proposal for

Meloidogyne incognita (Kofoid & White, 1919) Chitwood 1949

Southern root-knot nematode

Current Pest Rating: C

Proposed Pest Rating: C

Domain: Eukaryota; Kingdom: Metazoa;
Phylum: Nematoda; Family: Meloidogynidae

Comment Period: **04/08/2021 through 05/23/2021**

Initiating Event:

Requests for permits to move and use *Meloidogyne incognita*, southern root-knot nematode, for research purposes have been received by the CDFA Permits and Regulations program. The current rating and status of *M. incognita* in California is re-evaluated herein, and a permanent pest rating is proposed.

History & Status:

Background:

Root-knot nematodes (*Meloidogyne* spp.) were first being reported in California by E. A. Bessey in 1911. The name *Meloidogyne* is of Greek origin, meaning "apple-shaped female." It is one of the most extensively studied groups in the state with six species of significant economic concern: *M. incognita*, *M. javanica*, *M. arenaria*, *M. hapla*, *M. chitwoodi*, and *M. naasi* which was only found from golf courses in few counties of southern California. The host ranges of different species are variable but encompass most of the economically important agronomic and ornamental crops grown in California. The species are distributed widely in California's agricultural areas but show some regional and crop distribution preferences, with *M. incognita* being the only species that parasitizes cotton (Chitambar et al., 2018; Dong et al., 2007). There are four host races within *M. incognita* that can be separated by a host differential test. *Meloidogyne incognita* races 3 and 4 will reproduce on cotton, whereas races 1 and 2 will not (Kirkpatrick and Sasser, 1984).

Meloidogyne incognita is found worldwide in tropical and subtropical regions, and damage is worse in warmer climates. In California, *M. incognita* is found more often in the hot valleys of the interior. The effect of root-knot nematodes on plants can be dramatic. As a result of their feeding, large galls or “knots” are formed on the root systems, which impairs the plant’s ability to take up water and nutrients from the soil. The females are globose and sedentary at maturity. They establish a feeding site as juveniles and permanently remain within the plant root, exuding eggs out into the soil. The feeding site is a group of cells known as “giant-cells”, created when the nematode injects secretory proteins that stimulate changes within the parasitized cells. The injected cells rapidly become multinucleate when division occurs without cell wall formation. Giant-cells can be very large and act as serious nutrient sinks, producing large amounts of proteins that the nematode can use. Increase in the production of plant growth regulators from nematode feeding also plays a role in this increase in cell size and division. Root cells next to the giant-cells enlarge and divide rapidly, resulting in gall formation. *Meloidogyne* spp. generally reproduce by mitotic parthenogenesis, meaning that males are not necessary and viable eggs can be produced by females alone in the absence of fertilization. Vermiform males are rare and are only found when the population is subjected to an environmental stress, but they can mate with females. Eggs hatch in the soil and vermiform juveniles (mostly female sometimes male) swim to new roots (Mitkowski and Abawi, 2003).

Hosts: Abelmoschus esculentus (okra), *A. manihot* (bele), *Acacia confusa*, *Achillea millefolium* (yarrow), *Actinidia deliciosa* (kiwifruit), *Agave*, *Albizia lebbbeck* (Indian siris), *Alcea rosea* (Hollyhock), *Aloe vera* (true aloe), *Amaranthus* (amaranth), *A. blitoides* (spreading amaranth), *A. blitum* (livid amaranth), *A. deflexus* (perennial pigweed), *A. hybridus* (smooth pigweed), *A. spinosus* (spiny amaranth), *A. viridis* (slender amaranth), *Anacardium occidentale* (cashew nut), *Ananas comosus* (pineapple), *Anchusa azurea* (Italian alkanet), *Anethum graveolens* (dill), *Aptenia cordifolia*, *Arabidopsis thaliana*, *Araujia sericifera* (Arejishi), *Areca catechu* (betelnut palm), *Asparagus officinalis* (asparagus), *Basella alba* (malabar spinach), *Bassia scoparia*, *Bertholletia excelsa* (Brazil nut), *Beta vulgaris* (beet), *Bidens pilosa* (blackjack), *Brassica oleracea* (cabbages, cauliflowers), *B. oleracea* var. *gongyloides* (kohlrabi), *Brassicaceae* (cruciferous crops), *Calendula officinalis* (pot marigold), *Canavalia ensiformis* (jack bean), *Canna*, *C. indica* (canna lilly), *Cannabis sativa* (hemp), *Capsicum annuum* (bell pepper), *Cardiospermum halicacabum* (balloon vine), *Carica papaya* (pawpaw), *Chenopodium album* (fat hen), *C. murale* (nettleleaf goosefoot), *Chrysanthemum* (daisy), *Chicorium* (chicory), *Citrullus lanatus* (watermelon), *Cleome viscosa* (Asian spiderflower), *Clitoria ternatea* (butterfly-pea), *Cocos nucifera* (coconut), *Coffea* (coffee), *C. arabica* (arabica coffee), *C. canephora* (robusta coffee), *Colocasia*, *C. esculenta* (taro), *Commenlina benghalensis* (wandering jew), *Convolvulus arvensis* (bindweed), *Cordia myxa* (sebesten), *Cordyline fruticosa* (ti plant), *Coriandrum sativum* (coriander), *Cucumis anguria* (West Indian gherkin), *C. melo* (melon), *C. sativus* (cucumber), *Cucurbita argyrosperma* (silver-seed gourd), *C. maxima* (giant pumpkin), *C. moschata* (pumpkin), *C. pepo* (marrow), *Cucurbitaceae* (cucurbits), *Cullen corylifolium* (black-dot), *Curcuma alismatifolia*, *C. longa* (turmeric), *Cyperus* (flatsedge), *C. haspan*, *C. rotundus* (purple nutsedge), *Dahlia coccinea*, *Datura metel* (Hindu datura), *D. stramonium* (jimsonweed), *Daucus carota* (carrot), *Digitaria horizontalis*, *D. insularis* (sourgrass), *Dioscorea* (yam), *D. alata* (white yam), *D. batatas* (Chinese yam), *D. cayenensis* (Guinea yam), *D. esculenta* (Asiatic yam), *D. rotundata*, *Duranta erecta* (golden dewdrop), *Echinochloa crus-galli* (barnyard grass), *Emelia sonchifolia* (red tasselflower),

Eragrostis ciliaris (gophertail lovergrass), *Eryngium foetidum*, *Euphorbia heterophylla* (wild poinsettia), *Euphorbia prostrata*, *Euphorbia tirucalli* (Indian-tree spurge), *Fabaceae* (leguminous plants), *Ficus*, *F. benjamina* (weeping fig), *F. elastica* (rubber plant), *F. religiosa* (sacred fig tree), *Galinsoga parviflora* (gallant soldier), *Gazania* (treasure-flower), *Gloxinia*, *Gomphrena globosa* (globe amaranth), *Gossypium* (cotton), *Helianthus annuus* (sunflower), *Hemerocallis* (daylilies), *Hevea brasiliensis* (rubber), *Hibiscus cannabinus* (kenaf), *H. syriacus* (shrubby althaea), *H. trionum* (Venice mallow), *Ipomoea batatas* (sweet potato), *I. nil* (white ledge morning-glory), *I. purpurea* (tall morning glory), *Jacquemontia pentantha*, *Jasminum multiflorum* (star jasmine), *J. sambac* (Arabian jasmine), *Juglans* (walnuts), *Kalanchoe fedtschenkoi*, *Lactuca* (lettuce), *L. sativa* (lettuce), *L. serriola* (prickly lettuce), *Lagenaria siceraria* (bottle gourd), *Lantana camara* (lantana), *Lavandula angustifolia* (lavender), *Lens culinaris* subsp. *culinaris* (lentil), *Lotus corniculatus* (bird's-foot trefoil), *Luffa acutangula* (angled luffa), *L. aegyptiaca* (loofah), *Malpighia emarginata*, *M. glabra* (acerola), *Malva pusilla* (round-leaved mallow), *Mangifera indica* (mango), *Manihot esculenta* (cassava), *Medicago sativa* (lucerne), *Melilotus indica* (Indian sweetclover), *Mentha spicata* (Spear mint), *Momordica charantia* (bitter gourd), *Morinda citrifolia* (Indian mulberry), *Morus* (mulberrytree), *M. nigra* (black mulberry), *Murraya paniculata* (orange jessamine), *Musa* (banana), *M. acuminata* (wild banana), *Musa x paradisiaca* (plantain), *Nicotiana tabacum* (tobacco), *Oenanthe javanica*, *Olea europaea* subsp. *europaea* (European olive), *Ophiopogon japonicus*, *Oryza sativa* (rice), *Parthenium hysterophorus* (parthenium weed), *Passiflora edulis* (passionfruit), *Paulownia elongata* (elongate paulownia), *Persicaria posumbu*, *Phaseolus* (beans), *P. vulgaris* (common bean), *Phoenix dactylifera* (date-palm), *Phyla nodiflora*, *Piper methysticum* (kava), *P. nigrum* (black pepper), *Pithecellobium dulce* (Manila tamarind), *Pittosporum tobira* (Japanese pittosporum), *Platago lanceolata* (ribwort plantain), *Polianthes tuberosa* (tuberose), *Polygonum aviculare* (prostrate knotweed), *Pongamia pinnata* (Indian beech), *Portulaca oleracea* (purslane), *P. quadrifida* (chickenweed), *Prosopis juliflora* (mesquite), *Prunus* (stone fruit), *P. domestica* (plum), *P. persica* (peach), *Psophocarpus tetragonolobus* (winged bean), *Ptychosperma elegans* (solitaire palm), *Punica granatum* (pomegranate), *Radermachera sinica*, *Rhaponticum repens* (Russian knapweed), *Rollinia mucosa*, *Rosmarinus officinalis* (rosemary), *Rumex acetosa* (sour dock), *Saccharum officinarum* (sugarcane), *Samanea saman* (rain tree), *Sansevieria trifasciata* (mother-in-law's tongue), *Schinus terebinthifolius* (Brazilian pepper tree), *Sesamum indicum* (sesame), *Setaria viridis* (green foxtail), *Sida rhombifolia*, *Sinapis alba* (white mustard), *Solanaceae*, *Solanum americanum*, *S. lycopersicum* (tomato), *S. melongena* (aubergine), *S. nigrum* (black nightshade), *S. sisymbriifolium*, *S. tuberosum* (potato), *Spinacia oleracea* (spinach), *Tabebuia serratifolia*, *Tagetes erecta* (Mexican marigold), *Tephrosia vogelii* (Vogel's tephrosia), *Trachyspermum ammi*, *Veitchia merrillii* (Christmas palm), *Vernonia cinerea*, *Vigna angularis* (adzuki bean), *V. mungo* (black gram), *V. radiata* (mung bean), *V. unguiculata* (cowpea), *Viola pilosa*, *Vitex agnus-castus* (lilac chastetree), *V. trifolia*, *Vitis vinifera* (grapevine), *Washingtonia robusta* (Mexican fan palm), *Xanthosoma* (cocoyam), *Zea mays* (maize), and *Zingiber officinale* (ginger) (CABI-CPC, 2021).

Symptoms: Nematode feeding causes cell enlargement and proliferation and leads to the primary symptom of a galled root systems. On some hosts such as tomatoes, galls are obvious and can be up to one inch in diameter (Ploeg, 2013). But galled root systems should not be the only diagnostic test, as galls are not always formed, or can be very small, spindle shaped, or in spirals. Galls can also resemble

nodules caused by nitrogen-fixing bacteria. Sometimes the primary symptom is a proliferation of lateral root branches rather than galls. Carrots can suffer severe forking with galling mostly found on the lateral roots. On lettuce roots, galls are beadlike. On grasses and onions, galls are usually small swellings and barely noticeable. (Chitambar et al., 2018; Mitkowski and Abawi, 2003).

Numerous aboveground symptoms can also be observed, but these are also not diagnostic. Severely affected plants wilt readily, even when soil moisture is sufficient, because galled roots have less ability to absorb and transport water. Nutrient deficiency symptoms including chlorosis can also be observed because of a reduced ability of galled roots to absorb and transport nutrients, even when levels are adequate in the soil. Stunting is a frequent symptom. At high densities or with highly sensitive crops, root-knot nematodes can kill host plants, particularly if the high populations occur early in the growing season when root systems are small. Above ground, symptoms usually appear in clusters of plants or in patches of the field. (Mitkowski and Abawi, 2003; Chitambar et al., 2018).

Heavily infected roots are often badly discolored and rotted. This is due to the invasion of roots by fungi such as *Rhizoctonia*, *Fusarium* and *Pythium* which cause necrosis, and due to the breakdown of galled tissue by bacteria. A severe root rot of tomato caused by *M. incognita* and *R. solani* in California was associated with galled tissues and root exudations, but root decay did not develop when root exudates were continuously removed by leaching (Van Gundy et al., 1977).

Transmission: Root-knot nematodes move slowly through undisturbed soil, and in perennial crops, infestations will gradually radiate outward from an initial point of infection. Cultivation and other practices that move soil and plants will spread root-knot nematodes over longer distances. The length of a root-knot nematode life cycle varies among species but can be as short as two weeks. Nematodes in cooler regions typically have longer life cycles. Eggs may remain inside root tissue or may be released into the soil matrix. Eggs hatch at random and hatching does not require exposure to root exudates. Life cycles can be completed on tomato with average soil temperatures between 16.2°C and 20.0°C, but not at 35.4°C. (Ploeg and Maris, 1999). Second-stage juveniles move within the film of water that lines soil pores and are the infective stage. Stylets are used to penetrate root tips at the elongation zone. Once inside the plant root, nematodes migrate towards the vascular cylinder where they establish a feeding site. Once feeding is initiated, they become sedentary and undergo three additional moults to become pear or nearly spherical-shaped adults. The adult female lays 150–250 eggs in a gelatinous matrix on or below the surface of the root. The proportion of males in a population are typically low but may be found toward the end of the growing season, when populations are dense and host plants are under stress (McClure and Viglierchio, 1966).

Damage Potential: *Meloidogyne incognita* is found in many soil types. Damage and yield losses are generally more severe on coarse textured, sandy soils (Van Gundy, 1985). *Meloidogyne* infection causes a decrease in the size of the root system. Depending upon the host and the number of nematodes present, galls vary in size from minute to extremely large. Galls on trees and vines, are typically smaller than those on herbaceous plants. Infections can also be an aesthetic problem; in carrots, attack causes disfiguration with galling and splitting of the tap root, rendering the carrot unmarketable (Westerdahl et al., 2012). Aboveground symptoms include stunting, loss of quantity and

quality of yield, wilting during hot periods of the day, and increased susceptibility to foliage and wilt diseases (Mitkowski and Abawi, 2003).

Worldwide Distribution: Africa: *Algeria, Angola, Benin, Botswana, Burkina Faso, Cabo Verde, Cameroon, Central African Republic, Congo Democratic Republic of the, Côte d'Ivoire, Egypt, Eritrea, Ethiopia, Gambia, Ghana, Guinea, Kenya, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Niger, Nigeria, Réunion, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, Sudan, Tanzania, Togo, Tunisia, Uganda, Zambia, Zimbabwe*; Asia: *Afghanistan, Armenia, Azerbaijan, Bangladesh, Brunei, China, Georgia, India, Indonesia, Iran, Iraq, Israel, Japan, Jordan, Kazakhstan, Kyrgyzstan, Lebanon, Malaysia, Mongolia, Myanmar, Nepal, Oman, Pakistan, Philippines, Saudi Arabia, Singapore, South Korea, Sri Lanka, Syria, Taiwan, Tajikistan, Thailand, Turkey, Turkmenistan, Uzbekistan, Vietnam, Yemen*; Europe: *Albania, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Cyprus, Czechia, Estonia, Federal Republic of Yugoslavia, France, Germany, Greece, Hungary, Iceland, Italy, Latvia, Lithuania, Malta, Moldova, Montenegro, Netherlands, North Macedonia, Poland, Portugal, Romania, Russia, Serbia, Serbia and Montenegro, Slovakia, Slovenia, Spain, Switzerland, Ukraine, United Kingdom*; North America: *Antigua and Barbuda, Barbados, Belize, Bermuda, Canada, Costa Rica, Cuba, Dominica, Dominican Republic, El Salvador, Guadeloupe, Guatemala, Haiti, Honduras, Jamaica, Martinique, Mexico, Montserrat, Nicaragua, Panama, Puerto Rico, Saint Lucia, Saint Vincent and the Grenadines, Trinidad and Tobago, United States (Alabama, Arizona, Arkansas, California, Connecticut, Florida, Georgia, Hawaii, Illinois, Indiana, Kansas, Kentucky, Louisiana, Maryland, Mississippi, Missouri, New Mexico, New York, North Carolina, Oklahoma, Oregon, Pennsylvania, South Carolina, Tennessee, Texas, Utah, Virginia, Washington, West Virginia)*; Oceania: *American Samoa, Australia, Fiji, Kiribati, New Caledonia, New Zealand, Niue, Norfolk Island, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu*; South America: *Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, French Guiana, Guyana, Paraguay, Peru, Suriname, Uruguay, Venezuela*.

Official Control: *Meloidogyne incognita* is on the USDA's harmful organism list for Canada, French Polynesia, Jordan, and Mexico, (USDA-APHIS, 2021) and on the EPPO's A2 list for Jordan (EPPO, 2021).

California Distribution: There are official records from surveys, phytosanitary certification samples, and diagnostic samples from Butte, Colusa, Contra Costa, Fresno, Kern, Kings, Los Angeles, Marin, Mendocino, Merced, Placer, Riverside, Sacramento, San Bernardino, San Diego, San Joaquin, Santa Barbara, Solano, Sonoma, Stanislaus, Tulare, Ventura, and Yolo counties. Beet, cucumber, onion, soybean, olive, alfalfa, bean, tomato, hop, potato, nectarine, and grape are all frequently observed hosts.

California Interceptions: There has been one interception on African violets nursery stock from New York.

The risk *Meloidogyne incognita* would pose to California is evaluated below.

Consequences of Introduction:

- 1) **Climate/Host Interaction:** *Meloidogyne incognita* is widespread in tropical and sub-tropical areas. It is more common in hotter areas, such as California's inland valleys, but it has been detected in many climates, wherever its hosts are grown.

Evaluate if the pest would have suitable hosts and climate to establish in California.

Score: 3

- Low (1) Not likely to establish in California; or likely to establish in very limited areas.
- Medium (2) may be able to establish in a larger but limited part of California.
- **High (3) likely to establish a widespread distribution in California.**

- 2) **Known Pest Host Range:** The host range of *M. incognita* is very large, with hosts in many diverse families.

Evaluate the host range of the pest.

Score: 3

- Low (1) has a very limited host range.
- Medium (2) has a moderate host range.
- **High (3) has a wide host range.**

- 3) **Pest Reproductive Potential:** This species can reproduce with females only, and populations can increase exponentially. They disperse slowly on their own, with juveniles moving through soil.

Evaluate the natural and artificial dispersal potential of the pest.

Score: 2

- Low (1) does not have high reproductive or dispersal potential.
- **Medium (2) has either high reproductive or dispersal potential.**
- High (3) has both high reproduction and dispersal potential.

- 4) **Economic Impact:** Damage can be direct from nematode feeding and gall formation on the roots, or indirect as plants become more susceptible to attack from other types of pathogens.

Evaluate the economic impact of the pest to California using the criteria below.

Economic Impact: A, B, C

- A. The pest could lower crop yield.**
 - B. The pest could lower crop value (includes increasing crop production costs).**
 - C. The pest could trigger the loss of markets (includes quarantines).**
 - D. The pest could negatively change normal cultural practices.
 - E. The pest can vector, or is vectored, by another pestiferous organism.
 - F. The organism is injurious or poisonous to agriculturally important animals.
-

G. The organism can interfere with the delivery or supply of water for agricultural uses.

Economic Impact Score: 3

- Low (1) causes 0 or 1 of these impacts.
- Medium (2) causes 2 of these impacts.
- **High (3) causes 3 or more of these impacts.**

5) **Environmental Impact:** *Meloidogyne incognita* has an extremely large host range, including weeds and native plants. Once established in the soil, they are very difficult to eradicate.

Environmental Impact: A, E.

- A. The pest could have a significant environmental impact such as lowering biodiversity, disrupting natural communities, or changing ecosystem processes.**
- B. The pest could directly affect threatened or endangered species.
- C. The pest could impact threatened or endangered species by disrupting critical habitats.
- D. The pest could trigger additional official or private treatment programs.
- E. The pest significantly impacts cultural practices, home/urban gardening or ornamental plantings.**

Environmental Impact Score: 3

- Low (1) causes none of the above to occur.
- Medium (2) causes one of the above to occur.
- **High (3) causes two or more of the above to occur.**

Consequences of Introduction to California for *Meloidogyne incognita*: High

Add up the total score and include it here. 14

- Low = 5-8 points
- Medium = 9-12 points
- High = 13-15 points**

6) **Post Entry Distribution and Survey Information:** Evaluate the known distribution in California. Only official records identified by a taxonomic expert and supported by voucher specimens deposited in natural history collections should be considered. Pest incursions that have been eradicated, are under eradication, or have been delimited with no further detections should not be included.

Evaluation is 'High'. *Meloidogyne incognita* is widely established in California

Score: -3

- Not established (0) Pest never detected in California or known only from incursions.
 - Low (-1) Pest has a localized distribution in California or is established in one suitable climate/host area (region).
-

-Medium (-2) Pest is widespread in California but not fully established in the endangered area, or pest established in two contiguous suitable climate/host areas.

-High (-3) Pest has fully established in the endangered area, or pest is reported in more than two contiguous or non-contiguous suitable climate/host areas.

7) **The final score is** the consequences of introduction score minus the post entry distribution and survey information score: (Score)

Final Score: *Score of Consequences of Introduction – Score of Post Entry Distribution and Survey Information = 11*

Uncertainty:

None

Conclusion and Rating Justification:

Based on the evidence provided above the proposed rating for *Meloidogyne incognita* is **C**.

References:

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Responsible Party:

Heather J. Scheck, Primary Plant Pathologist/Nematologist, CDFA/PHPPS ECOPERS, 2800 Gateway Oaks Suite 200, Sacramento, CA 95833 Phone: (916) 654-1017, [permits\[@\]cdfa.ca.gov](mailto:permits[@]cdfa.ca.gov).

***Comment Period: 04/08/2021 through 05/23/2021**

*NOTE:

You must be registered and logged in to post a comment. If you have registered and have not received the registration confirmation, please contact us at [permits\[@\]cdfa.ca.gov](mailto:permits[@]cdfa.ca.gov).

Comment Format:

- ❖ Comments should refer to the appropriate California Pest Rating Proposal Form subsection(s) being commented on, as shown below.

Example Comment:

Consequences of Introduction: 1. Climate/Host Interaction: [Your comment that relates to “Climate/Host Interaction” here.]

- ❖ Posted comments will not be able to be viewed immediately.
- ❖ Comments may not be posted if they:
 - Contain inappropriate language which is not germane to the pest rating proposal;
 - Contains defamatory, false, inaccurate, abusive, obscene, pornographic, sexually oriented, threatening, racially offensive, discriminatory or illegal material;
 - Violates agency regulations prohibiting sexual harassment or other forms of discrimination;
 - Violates agency regulations prohibiting workplace violence, including threats.
- ❖ Comments may be edited prior to posting to ensure they are entirely germane.
- ❖ Posted comments shall be those which have been approved in content and posted to the website to be viewed, not just submitted.

Proposed Pest Rating: C
